Fundamentals & Basics of GTAW

1.0 INTRODUCTION:

Gas tungsten arc welding (GTAW) is a process in which the joining of metals is produced by heating therewith an arc between a non-consumable tungsten electrode and the work-piece (figure 1). The heated weld zone, molten metal, and tungsten electrode are shielded from the atmosphere by a covering of inert gas fed through the electrode holder. Because of the use of inert gas for the shielding of the arc, the process is also known as Tungsten Inert gas welding (TIG). Though Argon is commonly used as shielding gas but Helium & Argon-Helium mixtures are also used depending on the availability & job requirement.

In TIG welding filler metal may or may not be added. A weld is made by forming the arc and thereby melting the in the joint groove. The equipment and electrode in GTAW are different from other arc welding processes. The welding torch – its various components, position of filler wire, etc are shown in figure-2.

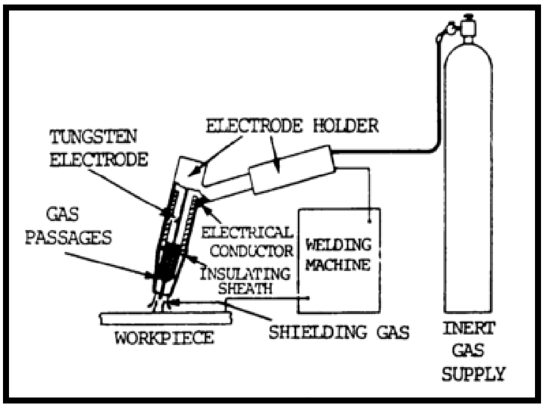

Figure-1: Schematic representation of GTAW process.

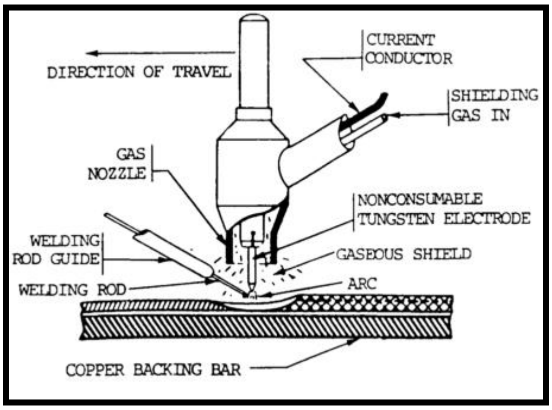

Figure-2: Schematic sketch of the GTAW torch.

The equipment consists of three parts – 1) the welding power source, 2) welding electrode holder & the tungsten electrode and 3) the shielding gas supply & the controls. Both AC & DC power sources are used with built-in high frequency (HF) unit. The power sources also control the gas and water flow during start & end of welding.

2.0 OPERATION OF THE GTAW PROCESS:

2.1 Power Sources – Constant current type Power Sources are generally used for TIG Welding. All metals except Aluminium, Magnesium and their alloys are welded with DC electrode negative polarity. AC is used for Aluminium, Magnesium and their alloys, Generators, Rectifiers and Invertors are used for DC supply while transformers or alternators are used for AC supply. Pulsed DC power sources are used for more accurate welds.

With DCEN (Tungsten electrode negative), heat generated at the work piece is much more than that at the electrode. (Roughly the heat distribution is 30% at negative and 70% at positive in GTAW). This helps in good weld penetration and also for keeping the electrode relatively cooler. The TIG welding power sources are shown in figure-3 & figure-4.

Figure-3: Photograph of TIG welding power source CHAMPTIG 300 AD

Figure-4: Photograph of TIG welding power source CHAMPTIG 300 P

With DC Electrode Positive, due to the flow of electrons from the job surface to the electrode, there is a cleaning action of the oxide layer on the job surface. This is useful in case of Aluminium etc. Since in case of AC, the electrode alternates between positive and negative, there is cleaning action combined with reasonably good penetration. Hence AC is preferred for metals like; Aluminium.

Pulsed DC Welding power sources and square Wave AC power sources are used for more controlled/precision welding applications.

2.2 Torch – GTAW torches hold the Tungsten electrode which conducts welding current to the arc, and provide a means for conveying shielding gas to the arc zone. Torches are rated in accordance with the maximum welding current that can be used without overheating. Typical torch characteristics are given below (Table-1). The torch & the various components are shown in figure-5 & figure-6.

Table-1: GTAW torch characteristics.

Torch Characteristics	Torch Size		
	Small	**Medium**	**Large**
Max Continuous Current	200 A	200A to 300 A	500 A
Cooling Method	Gas	Water	Water
Electrode Diameter	0.5mm to 2.5mm	1 mm to 4 mm	1 mm to 6.3 mm
Nozzle/Gas Cup-Diameter	6 mm to 16 mm	6 mm to 20 mm	10 mm to 20 mm

Most of the torches for manual applications have a head angle (angle between the electrode and handle) of 120 degree. Torches are also available with adjustable angles, 90 degree heads or straight line (pencil type) heads. Gas/current control switches are provided on the torch in most manual torches. Automatic welding torches are mounted on typical devises to suit the application. Gas cooled/ air cooled torches are cooled by the shielding gas and are used for low current applications. Water cooled torches have a continuous flow of water through the torch to keep the electrode cool. These are used for higher currents and generally in all automatic applications.

Figure-5: Photograph of GTAW torch with electrodes, cups, collets and gas diffusers

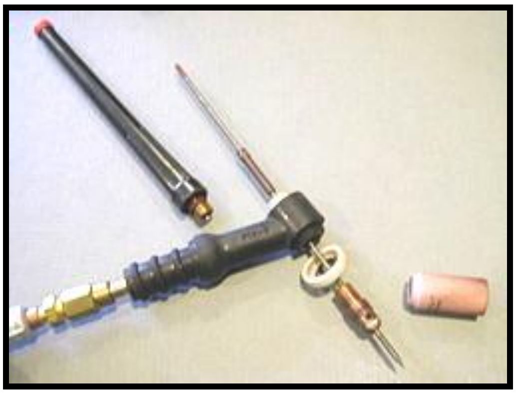

Figure-6: Photograph of GTAW torch – disassembled.

Collets or chucks are used to secure the electrode in the electrode holder/ torch. These are made of copper alloys and should be in good contact with electrode for proper current transfer and cooling.

Gas nozzle or cups which fit onto the head of the torch direct the shielding gas to the weld zone. These are made of heat resistant materials like ceramic or fused quartz. Water cooled metal nozzles are also used.

The size of the nozzle should ensure proper shielding coverage of the weld pool/ heat affected zone and also ensure smooth flow of gas. If the flow rate for a given nozzle diameter us excessive, I will lead to turbulence. Nozzle size selection depends on electrode size, type of joint, accessibility etc. length and internal contour of the nozzle is designed to give streamlined gas flow. Some recommended cup size combinations are given below for Argon shielding (Table-2).

Table-2: GTAW current selections.

Electrode Dia.	**Gas Cup**	**(EW Th Electrode)**	**(EWP Electrode)**
	Inner Dia.	DCEN	AC
mm	Inches	Current A	Current A
1.6	3/8	70-150	50-100
2.4	1/2	150-250	100-160
3.2	1/2	250-400	150-210

To ensure laminar flow of gas shielding gas, gas lenses are used inside the nozzle. Gas lenses are porous barrier diffusers designed to fit around the electrode or collet. Gas lenses produce a longer undistributed flow gases.

<u>2.3 Electrodes</u> – Tungsten and its various alloys are used as the non-consumable electrode in GTAW. Tungsten has a melting point of 3410 degree Celsius and hence does not melt due to the high temperature of the arc. Oxides of Cerium (CeO_2) Lanthanum (La_2O_3), Thorium (ThO_2) and Zirconium (ZrO_2) are generally added as alloying additions. The alloying additions are below 2% level.

The classification/ coding of Tungsten electrodes are given below (Table-3).

Table-3: GTAW electrode classifications.

AWS Classification	Color Coding	Alloying Element (Oxide Control)
EWP	Green	Pure Tungsten
EW Ce-2	Orange	Cerium (2%)
EW La-1	Black	Lanthanum (1%)
EW Th-1	Yellow	Thorium (2%)
EW Th-2	Red	Thorium (2%)
EW Zr-1	Brown	Zirconium (0.25%)
EWG	Grey	Any other, to be specified by manufacturer

Pure Tungsten electrodes (EWP) are used mainly with AC when they give a clean, balled end and good arc stability. Thoriated electrodes have (EWTh-1 & EW Th-2) better current carrying capacity and longer life as compared with pure Tungsten. They are preferred for DCEN applications, where they maintain the sharp while welding.

Ceriated electrodes (EW Ce-2) are a replacement for Thoriated series, especially because Cerium has no radioactive tendency unlike Thorium. These can be used with AC or DC. Lanthanated electrodes (EWZr-1) have characteristics that fall between pure and thoriated Tungsten. They are best suited for AC Welding since they combine the arc stability and balled end of pure Tungsten with the current capacity and starting characteristics of Thoriated Tungsten. Tungsten contamination of weld metal, which is likely with pure tungsten, is considerably reduced with alloyed electrodes. EWG electrode classification is for all other electrodes not specified. Manufacturer should specify the alloying additions in this case. Yttrium oxide, Magnesium oxide and higher alloying additions of Ce, La etc. are sometimes used.

The shape of the Tungsten electrode tip is an important process variable in GTAW. Hemispherical balled end formed in pure Tungsten or Zirconated Tungsten is preferred in AC welding. For DC welding, electrode tip is ground to specific included angles. Penetration increases and width of bead decreases with increasing included angle.

2.4 Shielding Gas – Inert gas shielding is provided for shielding the liquid metal, heat affected zone, hot filler metal & Tungsten electrode. Argon & Helium are commonly used. Typical gas flow rates are in the range of 7 to 16 litres per minute.

2.5 High Frequency unit – High frequency system enables the welder to start an arc without touching the base metal with the electrodes. This is an attachment to the welding power source and provides a high voltage at a high frequency, which is superimposed on the welding circuit. In DC welding the HF is switched off after arc initiation. In AC welding, since the arc is continuously switched on & off as the current goes through zero every time as it moves from positive to negative & vice-versa, the HF is continuously switched on to maintain the arc.

2.6 Pre-flow & Post-flow Control – Pre-flow is the gas-flow prior to the arc initiation and post-flow is the gas-flow after the arc extinction. Pre-flow helps in removing the atmospheric contaminants before initiation of arc and post-flow protects the hot metal after welding stops. These are generated inbuilt into the system.

2.7 Current Up-slope & Down-slope Controls – These controls help is monitoring the time taken for the current to reach the peak when Power is switched on and the current to reach zero when Power is switched off. Optimum slopes are kept for good arc initiation and good crater filling at the end of the weld.

2.8 Filler Wire – In TIG Welding, Filler wire is added to the weld external to the torch and is independently controlled. This enables the welder to add it whenever and wherever required. Generally, the filler wires have matching chemistry with respect to the base metal. For mechanized welding, continuous wire feed is done, if required. Also, the filler wire is preheated sometimes to improve melting rates.

2.9 Back-up Purge – While making root passes, to remove air from the backside of the weld, inert gases are passed to ensure clean weld. Argons/ Helium/ Nitrogen are used for back purging.

2.10 Striking the Arc – Striking the arc may be done by any of the following methods.

1. Touching the electrode to the work momentarily and quickly withdrawing it.

2. Using an apparatus that will cause a spark to jump from the electrode to the work.

3. Using an apparatus that initiates and maintains a small pilot arc, providing an ionized path for the main arc.

4. High frequency arc stabilizers are required when alternating current (AC) is used (2). High frequency arc initiation occurs when a high frequency, high voltage signal is superimposed on the welding circuit. High voltage (low current) ionizes the shielding gas between the electrode and the work-piece, which makes the gas conductive and initiates the arc. Inert gases are not conductive until ionized. For DC welding, the high frequency voltage is cut off after arc initiation. However, with AC welding, it usually remains on during welding, especially when welding aluminum.

5. When welding manually, once the arc is started, the torch is held at a travel angle of about 15 degrees. For mechanized welding, the electrode holder is positioned vertically to the surface.

The various steps in GTAW welding technique is schematically shown in the figure-7.

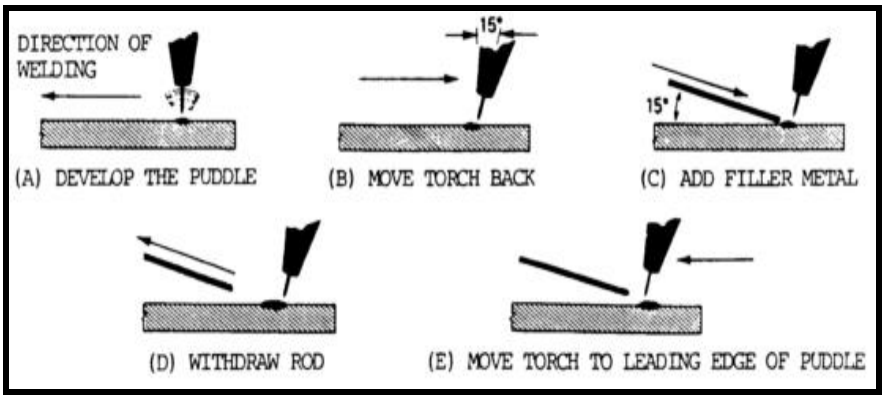

Figure-7: Schematic representation of welding technique in manual GTAW process.

The tip preparation in TIG welding depends on the type of polarity and welding conditions and plays a significant role to achieve the desired properties. A schematic sketch of preparation of tungsten electrode is shown in figure-8 for reference.

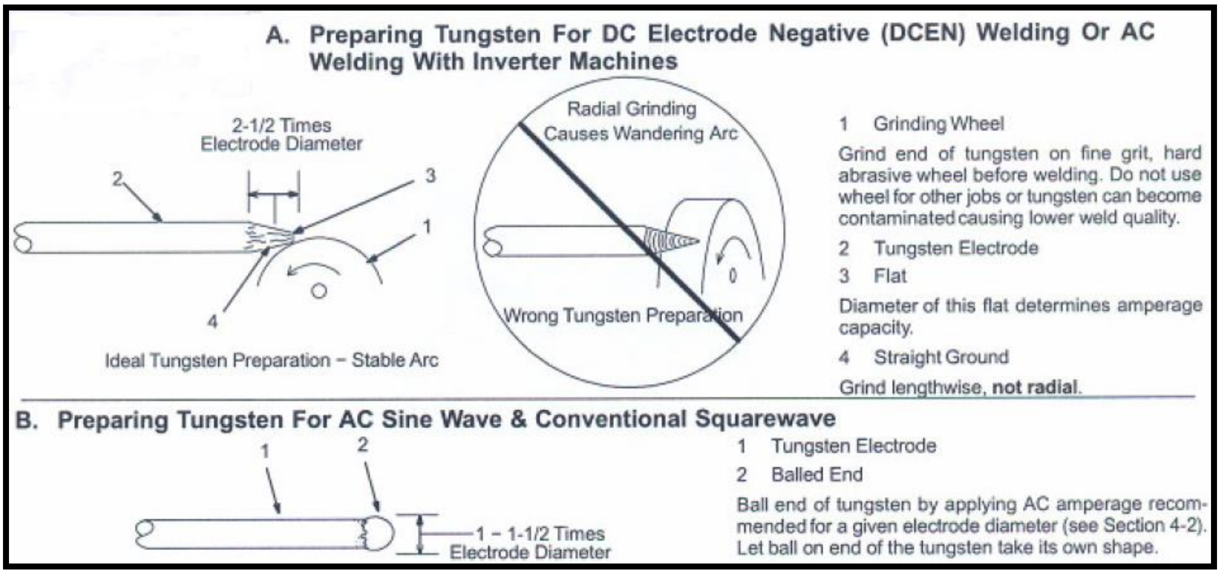

Figure-8: Schematic representation of tip preparation of GTAW electrodes.

3.0 VARIOUS WELDING TECHNIQUES FOR GTAW PROCESS:

3.1 Butt-Weld – While welding a butt joint (figure-9), the weld pool is formed at the centre of the adjoining edges. When finishing, decrease the heat (amperage) to aid in filling the crater.

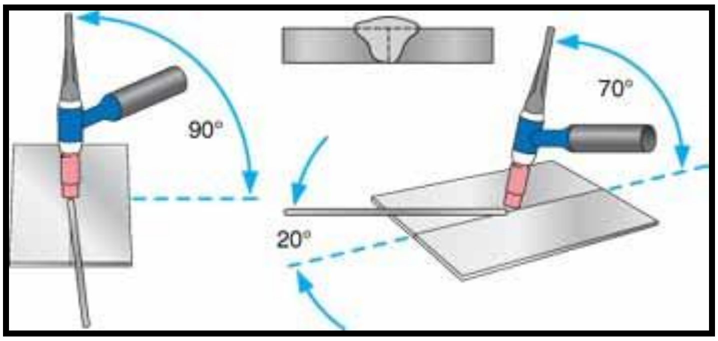

Figure-9: Schematic representation of butt-welding technique in manual GTAW process.

3.2 Lap Joint – For a lap-weld (figure-10), the weld pool is so formed that the edge of the overlapping piece and the flat surface of the second piece flow together. Since the edge tends to melt faster, filler rod is dipped next to the edge to ensure enough filler metal to complete the joint.

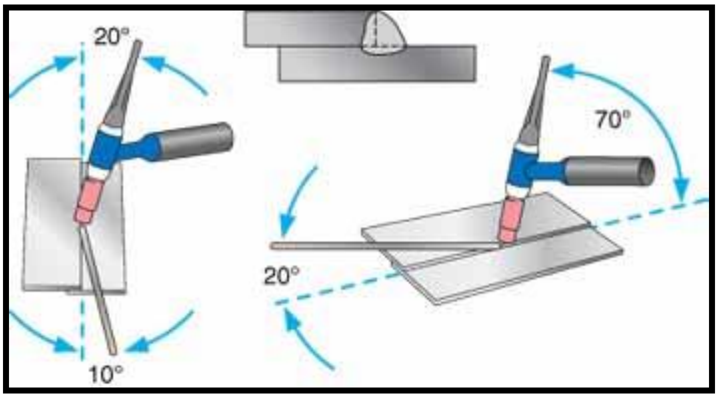

Figure-10: Schematic representation of lap-welding technique in manual GTAW process.

3.3 T-Joint – While welding a T-joint (figure-11), the edge and the flat surface are to be joined together. The edge tends to melt faster so the angle of the torch is directed to the flat surface for more heat and extend the electrode beyond the cup to hold a shorter arc. The filler rod is hold where the edge is melting.

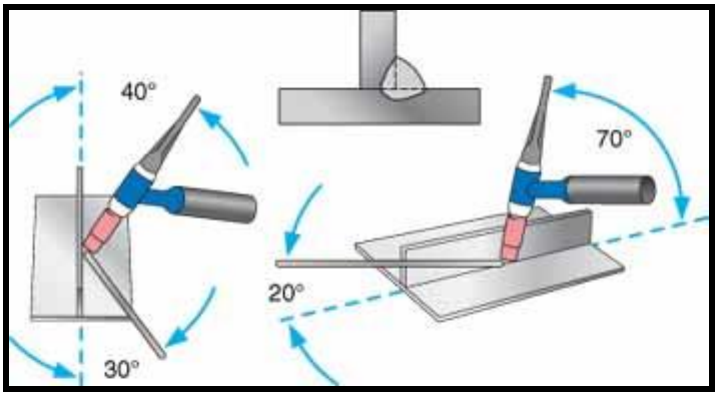

Figure-11: Schematic representation of T-joint welding technique in manual GTAW process.

3.4 Corner Joint – For a corner joint (figure-12), both edges of the adjoining pieces shall be melted and the weld pool shall be kept on the joint centerline. A convex bead is necessary for this joint, so a sufficient amount of filler metal is needed.

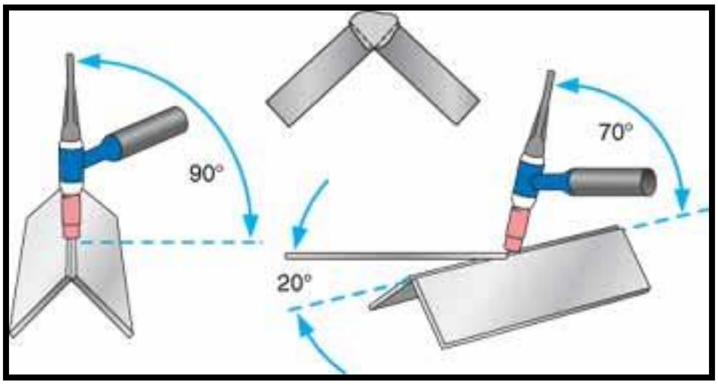

Figure-12: Schematic representation of Corner joint technique in manual GTAW process.

4.0 ADVANTAGES & LIMITATION OF GTAW PROCESS:

4.1 Advantages

1. Considering the common welding processes, weld deposits by GTAW is the cleanest among all.
2. Versatile and suitable for almost all metals and alloys used by industry. Moreover, it is especially useful for joining aluminum and magnesium which form refractory oxides, and also for the reactive metals like titanium and zirconium, which dissolve oxygen and nitrogen and become brittle if exposed to air while melting. Apart from above, TIG process can also be used to weld Stainless steel, Nickel alloys such as Monel and Inconel, Copper, Brass, Bronze, and even Gold.
3. The process provides more precise control of the weld than any other arc welding process, because the arc heat and filler metal are independently controlled.
4. Visibility is excellent because no smoke or fumes are produced during welding.
5. Absence of slag or spatter eliminates the intermediate cleaning between the passes or on a completed weld.
6. GTAW process is extremely suitable for joining thin base metals because of excellent control of heat input.
7. Low distortion.

4.2 Limitations

1. The process is slower than other conventional arc welding processes.
2. Weld metal deposition rates are lower.
3. Transfer of molten tungsten from the electrode to the weld causes contamination. The resulting tungsten inclusion is hard and brittle.
4. Exposure of the hot filler rod to air using improper welding techniques causes weld metal contamination.
5. Total cost of welding is higher compared to other processes. Argon and helium used for shielding the arc are relatively expensive.
6. The hand-eye coordination is essential to accomplish the weld. So, the process is difficult to learn and it requires a great deal of practice to become proficient.